machinery or buildings, and thereby produce a better or a cheaper article; but in building a railroad this cannot be readily done. If the road bed is not originally well laid out and constructed, and capable of being run cheaply and safely it can only be reorganized at a cost equaling that of a new line. All advantages must be secured, and the outlay made in the first instance, if the stockholders are to receive any advantage from the money they have invested.

RINGING BELLS.

By John W. Nystrom.

(Continued from page 376.)

In connection with the article on "Intonation of Chime Bells," published in the May number of the Journal, it is proposed to give the dimensions and weights of bells corresponding to each keynote in the eight octaves. For this purpose it is necessary to assume an average proportion of form, particularly that of the diameter at the bell-mouth to the thickness of the sound-bow, namely, $D:S = 1000:78$.

D = diameter of the bell in inches.

S = thickness of the sound-bow in inches.

n = double vibration per second, corresponding to the pitch of tone.

W = weight of the bell in pounds avoirdupois.

Diameter, $D = \dfrac{20592}{n}$. $\log.D = 4{\cdot}3136985 - \log.n.$

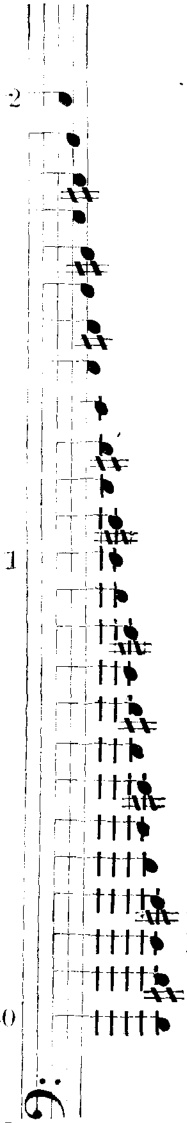
Weight, $W = \dfrac{204320000000}{n^3}$. $\log.W = 11{\cdot}3103144 - 3\log.n.$

The following tables of diameter and weight of bells are calculated from the above formulas, in which it is assumed that $S = 0{\cdot}078D$. For other proportions of S and D the diameter and weight of the bell will vary accordingly.

In old peals, all the bells are generally made of the same proportion, and even now some bellfounders hold to the old custom, probably for the reason that it is then easier to make the bell of correct pitch. When the proportion of S and D varies, as it should do for properly graduating the timbre in peals, it requires more knowledge of acoustics to make the bells right.

TABLE I.

Keynote, Diameter and Weight of Ringing Bells.

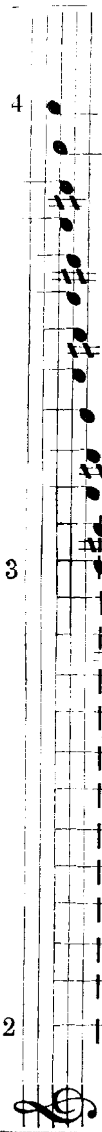


Keynote.	Diameter, Inches.	Weight, Pounds.	Remarks on Bells and Musical Instruments.
2 C	156·	88,836	
B	165·27	105,645	Great Bell of Nishni-Nov- [gorod.
A♯	175·11	125,635	
A	185·52	149,405	
G♯	196·55	177,674	St. Ivan's Bell. Cast 1817.
G	208·24	211,291	
F♯	220·62	251,267	
F	233·74	298,813	
E	247·64	355,380	
D♯	262·36	422,573	
D	277·95	522,543	Great Bell of Moscow. [Cast 1736.
C♯	294·50	597,656	
1 C	312·	710,688	
B	330·56	845,285	Trombone Basso, lowest [note.
A♯	350·21	1,005,100	
A	371·04	1,195,240	
G♯	393·10	1,421,400	
G	416·47	1,690,300	
F♯	441·24	2,010,100	
F	467·48	2,390,600	
E	495·50	2,844,900	Contra Basso, lowest note.
D♯	524·72	3,380,600	
D	555·93	4,020,400	Contra Fagotto, lowest [note.
C♯	589·00	4,781,500	
0 C	624·	5,685,510	Bombardone, lowest note.

* St. Paul, London. Cast 1716.
‡ Bell of St. Peter's, Rome.
† Lincoln, Eng., 1834.
|| Bell of Montreal. Cast 1847.

TABLE II.

Keynote, Diameter and Weight of Ringing Bells.

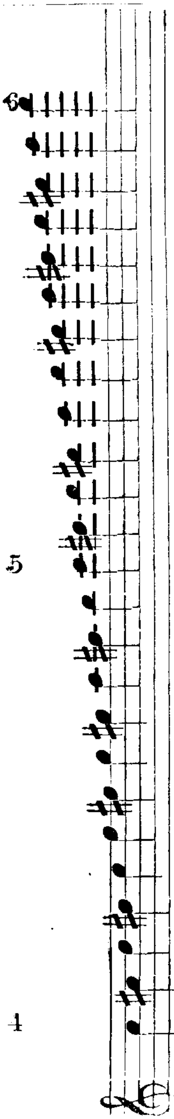


Keynote.		Diameter, Inches.	Weight, Pounds.	Remarks on Bells and Musical Instruments.
4	C	39·	1,388	
	B	41·32	1,650	
	A♯	43·78	1,964	
	A	46·38	2,334	Standard tuning fork, 440 vib.
	G♯	49·14	2,776	
	G	52·06	3,301	Highest note on Bombardone.
	F♯	55·15	3,926	
	F	58·43	4,669	Tenor bell, St. Mark's Ch., [Phila.
	E	61·91	5,552	Highest note on Contra Fag- [otto.
	D♯	65·59	6,603	
	D	69·49	7,852	Tenor bell, St. Stephen's Ch., [Phila.
	C♯	73·62	9,338	Old Lincoln. Cast 1610.
3	C	78·	11,104	
	B	82·64	13,206	
	A♯	87·55	15,705	
	A	92·76	18,675	Bell of Brussels, Belgium.*
	G♯	98·28	22,212	Oxford, Gr't Tom. C't 1680.†
	G	104·12	26,412	Bell of Cologne. Cast 1447.
	F♯	110·31	31,409	York, England. C't 1845.‡
	F	116·87	37,350	Bell of Erfurt. Cast 1487.‖
	E	123·82	44,422	Bell of Westminster, Eng.§
	D♯	131·18	52,822	Bell of Olmutz, Bohemia.¶
	D	138·98	62,816	Lowest note on Clarinetto, B fl.
	C♯	147·25	74,707	Lowest note on Clarinetto, A.
2	C	156·	88,836	

‡ Lowest note on the Clarinetto C. ‡ Lowest note on Guitar.
¶ Bell of Vienna, Austria. ¶ Bell of City Hall, New York.
¶ New bell of St. Paul's, London, 1881.

TABLE III.

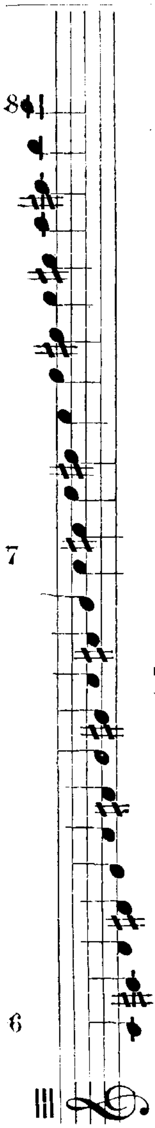
Keynote, Diameter and Weight of Ringing Bells.



Keynote.		Diameter, Inches	Weight, Pounds.	Remarks on Musical Instruments.
6	C	9·750	21·69	Highest note on C Flute.
	B	10 33	25·79	Highest note on C Clarinetto.
	A♯	10·94	30·67	
	A	11·60	36·48	
	G♯	12·28	43·38	Highest note on Clarinetto A.
	G	13·02	51·59	
	F♯	13·79	61·34	
	F	14·61	72·95	
	E	15·48	86·76	
	D♯	16·40	103·2	
	D	17·37	122·7	
	C♯	18·41	145·9	
5	C	19·5	173·5	
	B	20·66	206·3	
	A♯	21·89	245·4	
	A	23·19	291·8	
	G♯	24·57	347·0	
	G	26·03	412·7	
	F♯	27·58	490·8	
	F	29·22	583·6	Lowest note on Piccolo E flat [Flute.
	E	30·96	694·1	
	D♯	32·80	825·3	
	D	34·75	981·5	Lowest note on Piccolo C, [Flute.
	C♯	36·81	1167·	
4	C	39·00	1388·	

TABLE IV.

Keynote, Diameter and Weight of Ringing Bells.



Keynote.	Diameter, Inches.	Weight, Pounds.	Remarks on Musical Instruments.
C	2·437	0·339	Produced by the wings of a gnat.
B	2·582	0·403	
A♯	2·736	0·479	
A	2·899	0·570	
G♯	3·071	0·678	
G	3·254	0·806	
F♯	3·447	0·958	
F	3·652	1·140	
E	3·869	1·356	
D♯	4·200	1·612	Highest note of Piccolo E flat [Flute.
D	4·323	1·917	
C♯	4·601	2·280	
C	4·875	2·71	Highest note of Piccolo C Flute.
B	5·165	3·224	
A♯	5·472	3·834	
A	5·797	4·560	
G♯	6·142	5·422	
G	6·507	6·448	
F♯	6·894	7·668	
F	7·304	9·199	
E	7·739	10·84	
D♯	8·200	12·90	
D	8·686	15·34	
C♯	9·203	18·24	
C	9·750	21·69	

The Moscow great bell is the largest ever cast, being 272 inches in diameter and answers to the keynote D in the second octave, and weighs 432,200 pounds. It does not correspond exactly with the accompanying tables, for the reason that the sound-bow is $S = 0{\cdot}084D$.

The lowest note C, in the table, making $n = 33$ double vibrations per second, requires a bell of 52 feet in diameter, weighing 2550 tons, but by making the sound-bow $S = 0{\cdot}05D$, the same note would require a bell of only 400 inches, 33·3 feet, in diameter, weighing 430 tons. If the question was only to make a bell that would produce the lowest note C, making $n = 33$ double vibrations, without any other condition, the sound-bow may be taken $S = 0{\cdot}01D$, which would make the diameter only 80 inches, or 6 feet 8 inches, and the bell would weigh 1536 pounds. On the other hand, if the sound-bow is taken $S = 0{\cdot}1D$, which is sometimes done in bells, then the diameter for the same note would be 800 inches, or 66 feet 8 inches, and the weight of that bell would be 15,360,000 pounds or 6857 tons.

The above examples are only to show how the dimensions and weight of a bell can vary for the same keynote.

The preceding tables give the diameter and weight of bells of the most ordinary proportions.

[The discussion of this subject may be continued in a future number of the JOURNAL.]

Distribution of Energy in the Normal Solar Spectrum.—In the experiments which led Langley to the conclusion that the rays of light and heat coincide in intensity he found that the actual amount of energy which is required in a ray in order to make its presence evident through photography is less than $\frac{1}{100000000}$ of the energy which would be required, under the most favorable conditions, to produce a perceptible change in the most delicate galvanometer, by means of the most delicate battery. Langley's first paper presented the result of more than 15,000 galvanometer observations during a single year. In view of the rapid and extreme changes of atmospheric transparency many successive years would doubtless be required to secure the greatest possible exactness. He expects, by means of his observations, to arrive at a satisfactory determination of the actual amount of heat which the earth receives from the sun.—*Ann. de Chim. et de Phys.* C.

RADIO-DYNAMICS: UNIVERSAL PHYLLOTAXY.

By Pliny Earle Chase, LL.D.

Bonnet's discovery of the tendency in plant-growth to arrangement in cyclical spirals, seems to have been wholly empirical. The law of formation is simple, each of the phyllotactic numbers, after 1 and 2, being obtained by adding the two preceding terms of the series. Such simplicity might have suggested an early extension of the law into other fields of science, if it had been subjected to an earlier mathematical investigation, but for fifty years it was regarded as marking a curious, though inexplicable and perhaps accidental harmony.

In 1849, some of the professors and students of Harvard University became convinced that a law, which is so widely prevalent, must have some reason for its being. Chauncey Wright, in the *Mathematical Monthly*, showed that it represented a tendency to division in extreme and mean ratio, a tendency which distributes leaves and branches in the way that is most favorable for nourishment and growth. Peirce and Hill (*ante*, p. 141) extended the law to the planetary system. The orbital period of Uranus is very nearly $\frac{1}{2}$ of that of Neptune; Saturn, $\frac{1}{3}$ of Uranus; Jupiter, $\frac{2}{5}$ of Saturn; Asteroid 139, $\frac{2}{5}$ of Jupiter; Mars, $\frac{2}{5}$ of Asteroid 139; Earth, $\frac{1}{2}$ of Mars; Venus, $\frac{8}{13}$ of Earth; Mercury, $\frac{2}{5}$ of Venus.

Laplace's discussion of the curious relations among the satellites of Jupiter furnished a satisfactory explanation of an exact commensurability which is uncommon in natural phenomena. His explanation was grounded upon elementary laws of oscillation, which should be operative in molecular, as well as in cosmical movements. We may, therefore, be justified in looking for indications, in chemical atoms, of tendencies which are variously developed in the realms of time and space.

It is easy to detect exact harmonies of sound when there are only a few thousand consonances in a second, but in luminous or other æthereal vibrations the case is different. I have shown (Note 149, *Proc. Amer. Phil. Soc.*, xix, 600) that if there are two harmonic light waves, the slower oscillating 1670 times, while the swifter oscillates 1843 times, there may be more than 300,000,000,000 coincidences of phase per second, and yet mathematical tests, which are commonly satisfactory, may indicate a possibility that the harmony is merely accidental. For this reason it is always desirable, when practicable, to study harmonic groups rather than isolated harmonies.

In the discussions of Prout's hypothesis I do not find that any one has tried to test its general probability by mathematical methods. Whatever doubts may be felt as to the value of any given test, in a solitary instance, may be removed when it is taken only as a means of estimating comparative probabilities. In making my comparisons I have sought to neutralize the effects of personal equation or bias, as well as of accidental or empirical coincidence, by adopting Gerber's method of grouping and Clarke's recalculation of atomic weights. In view of the *á priori* probability of tendencies to division in extreme and mean ratio, I assume that the ratio of probability to improbability, in each instance, is at least $\frac{1}{4}$ D : (T — O); D being the tested divisor, T the theoretical atomic weight or nearest exact multiple of D, and O the observed atomic weight, according to Clarke's table. I have added Rb and Tl to Gerber's list of monatomic elements, and Bo, Ta and V to his tri- and pentavalent-list.

If we designate the several probabilities by $p_1, p_2, \ldots p_{64}$, that of Li being p_1, and that of Yb, p_{64}, the formula for aggregate probability, $P_n = p_a\, p_b \ldots p_n$, when applied to the several groups and to all the elements, gives the following results:

RELATIVE PROBABILITY.

Groups.	Hydrogen.	Gerber.	Phyllotactic.
Monatomic,	32·083	1·	1·232
Tri- and Pentavalent,	1·	24·916	24·916
Di- and Tetratomic,	1·	5375080·	7780740·
Metallic,	89507·6	1·	67·267
Aggregate,	1·	46·637	5592·649
Mean,	1·	1·062	1·144

My surprise at finding that the aggregate evidence of harmonic influence is so much greater in favor, both of Gerber's divisors and of my own, than in favor of the hypotheses of Dalton and Prout, will, doubtless, be shared by many. The uniformity of the evidence, in the separate groups as well as in the aggregate, that the phyllotactic divisors are more significant than those which are only approximately phyllotactic, will awaken no surprise in the minds of those who have learned that cyclical undulations in elastic media must be harmonic.

After I had found the above relations, Dr. Thomas Hill suggested the application of similar tests to the surd divisors, $\frac{1}{2}(3-\sqrt{5})$ and $\frac{1}{2}(\sqrt{5}-1)$. These surds represent the division in extreme and mean ratio, towards which the phyllotactic ratios continually tend. Dr. Hill's participation in Peirce's investigations gave him an interest in other researches of a like kind. As he was inclined to look upon perfect commensurability, such as Laplace found in the Jovian system, as exceptional, he thought that the fundamental ratios, $S_1 = \cdot 381966$ and $S_2 = \cdot 618034$, might be more exactly represented in atomicity than any of their approximations. The thought had so much likelihood that I gladly undertook the needful calculations, getting the results which are given in the following table.

RELATIVE PROBABILITY.

Groups	S_2	S_1	H.	Gerber.	Phyllotactic.
Monatomic,	2·085	1·00	30402·95	947·66	1167·08
3 and 5,	1·000	2·12	516·46	12867·90	12867·90
2 and 4,	1·000	2102·03	103214·80	$5548(10)^8$	$8031(10)^8$
Metallic,	1·840	3·28	89507·60	1·00	67·27
Aggregate,	1·000	3816·79	$378(10)^{14}$	$17633(10)^{14}$	$21145(10)^{16}$
Mean,	1.000	1·14	1·82	1·93	2·08

There is evidence, therefore, in each of the groups as well as in the aggregate, of a tendency to division in extreme and mean ratio at the very beginnings of chemical activity. In the di- and tetratomic group the probable influence of S_2 is to the probability of accidental or unknown influence only as 1·446 : 1, or very nearly as 13 : 9. Even this ratio, however, is satisfactory as an indication of incipient action, and suggests the belief that in the "nascent state," in the "fourth state of matter," or in some other approximation to the æthereal condition, S_1 and S_2 may be found to have as great a degree of relative importance as belongs to the phyllotactic divisors in the above comparisons. Dextro- and lævo-gyration, in plant-growth, in cometary and satellite revolution, and in optical chemistry, may, perhaps, represent the opposite tendencies of the two surd divisors.

The aggregate probability of hydrogen influence upon atomicity is more than 9,900,000,000,000 times as great as the aggregate probability of the influence of S_1. The corresponding phyllotactic probability is more than 5592 times that of hydrogen, or more than 55,400,-

000,000,000,000 times that of S_1, the latter being more than 3816 times that of S_2. Some helpful hints may, perhaps, be drawn from the fact that the greatest superiority of S_1 and S_2, as well as of the phyllotactic and approximately phyllotactic division over the hydrogen division, is found in the artiad group.

Thus, in every direction, multiply the evidences of the importance in all physical researches, of paying heed to the blended sway of inertia and elasticity. The principles which I applied successfully, in 1863, to barometric estimates of the sun's mass and distance (*Proc. Amer. Philos. Soc.*, ix. 287, 288; x. 375, 376, foot note) have been abundantly exemplified in every field in which I have sought for their application, and now I find them at the threshold of material structure, where cohesive and chemical attractions first show themselves. I do not wonder, then, when I find that the virtual areas of synchronous planetary reaction, or the mean instantaneous areas which a particle at sun's surface *tends* to describe about any given planet, are approximately phyllotactic. They evidently vary as $\sqrt{mr}$, and the closeness of the phyllotactic approximations is shown in the following table. The common ratio, $\frac{3}{4}$, is twice the phyllotactic ratio $\frac{3}{8}$. The factor 2 is also phyllotactic, indicating, perhaps, the reciprocal influences of equal action and reaction upon which each of the harmonies is grounded.

	Harmonic areas.	Mean virtual areas		Difference.
α	40·256	Jupiter,	40·587	— ·331
$\beta = \frac{3}{4}\,\alpha$	30·192	Saturn,	30·063	+ ·129
$\gamma = \frac{3}{4}\,\beta$	22·644	Neptune,	22·675	— ·031
$\delta = \frac{3}{4}\,\gamma$	16·983	Uranus,	16·782	+ ·201
ε	1·000	Earth,	1·000	·000
$\zeta = \frac{3}{4}\,\varepsilon$	·750	Venus,	·749	+ ·001
$\eta = \frac{3}{4}\,\zeta$	·562	....	....	....
$\theta = \frac{3}{4}\,\eta$	·422	Mars,	·404	+ ·018
$\iota = \frac{3}{4}\,\theta$	·316	....	....	....
$\varkappa = \frac{3}{4}\,\iota$	·237	....	....	....
$\lambda = \frac{3}{4}\,\varkappa$	·178	Mercury,	·162	+ ·016

If earth were rotating with the speed which a coincidence of Laplace's limit, with the equatorial surface would give it, the time of rotation would be $2\pi\sqrt{r \div g} = 5073{\cdot}8$ seconds. Its coefficient of orbital rotation, therefore, is $86164{\cdot}1 \div 5073{\cdot}8 = 16{\cdot}982$, which is equivalent to $\delta \div \varepsilon$. It is also nearly* equivalent to $a^{\frac{3}{4}}$, the nucleal radius in an expanding or condensing nebula varying as the $\frac{3}{4}$ power of Laplace's limiting radius. The locus of secular perihelion, or incipient rupture, for Uranus, is nucleally central between the mean loci of Jupiter and Neptune. I have often invited attention to the harmonic importance of the preponderating mass of Jupiter and the central position of Earth in the belt of greatest condensation. These renewed evidences of that importance lead me, through the doctrine of conservation of energy, to supplement Laplace's two laws of constancy by a third, viz.: *The sum of all the instantaneous virtual areas in a system will always remain invariable.*

The universality of photo-dynamic or radio-dynamic relations may be further illustrated by a new deduction of the identity of luminous and elementary gravitating velocity, which I first published in 1869 (*Proc. Am. Phil. Soc.*, xi. 103–107), but of which I gave foreshadowings nearly six years before. (*Ib.*, ix, 285, 357, 408 ; x, 269, *et al.*)

Coulomb's torsional formula may be applied to Sun's rotation, or circular oscillation, by taking Sun's equatorial semi-diameter, r_o, as the radial unit:

$$\int = \frac{m}{2} = \frac{W}{2} \cdot \frac{\pi^2 a^2 r_o}{gt^2} \; ;$$

$$\pi^2 a^2 r_o = \pi^2 l = gt^2 ; \; gt = v_\lambda = \textit{velocity of light}. \qquad (1)$$

If Sun's apparent semi-diameter is $961''.83$, Earth's semi-axis major $(\rho_3) = 214{\cdot}45 \; r_o$; g at Sun's equatorial surface $= {\cdot}0000003909446 \; r_o$; $v\lambda = \rho_3 \div 497{\cdot}827 = {\cdot}4307721 \; r_o$. Therefore, by substituting in (1), $t = 1101875$ sec.; solar rotation $= 2t = 25{\cdot}506$ days.

Haverford College, March 6, 1882.

Equi-potential Curves.—M. Guêbhard has studied the colored rings, which are produced in a mixture of acetates of copper and lead under a thin leaf metal, placed at an equal distance from vertical needles, which are attached to the poles of a battery of high tension. The curves appear to coincide with the equi-potential systems, which the formula of Kirchhoff gives for a similar distribution of electric poles on an indefinite plane.—*Chron. Industr.* C.

* The difference is $6\frac{1}{4}$ per cent. which corresponds very closely with the secular eccentricity of Jupiter.

A THERMOGRAPH:

A New Apparatus for Making a Continuous Graphical Record of the Variations of Temperature.

By G. Morgan Eldridge.

[A Paper read at the Stated Meeting of the Franklin Institute, April 26, 1882.]

The instrument under consideration is a thermograph for recording the atmospheric temperature, the fluctuations of which are much less regular and more frequent than one who has not made a study of it would suppose. It records the temperature directly from the column of mercury in the tube of a thermometer by dots or perforations upon a sheet of paper previously ruled with degrees and hours.

Its principal parts are, as shown in Fig. 1 of Plate;

1st. A thermometer in the form of an ordinary mercury thermometer, but open at the top of the tube and having a wire entering the bulb and connected to one pole of a battery, the other pole of which is connected to the mechanism of the instrument.

2d. An upright cylinder revolving by clockwork, covered with a paper which is divided vertically into 24 parts by lines representing the hours, and horizontally by lines representing the degrees.

3d. A bar raised and lowered by mechanism driven by clockwork, furnished below with a needle entering the tube of the thermometer, and carrying a pencil—or preferably a point—driven forward by a small electro-magnet when the circuit is closed by the needle entering the mercury, and then making a mark at the proper place upon the paper and indicating the temperature.

The bar carrying the needle rises about half an inch from the point at which the needle leaves the mercury and then descends until the needle again touches the mercury, whether that in the meantime shall have risen or fallen, when the point makes its mark upon the paper and the bar again commences to rise.

This movement is accomplished by the mechanism shown in the drawing, of which only the wheel *E*, gearing into the rack upon the needle-bar, is shown in Fig. 1, but which is shown in full and upon an enlarged scale in Fig. 2, which is a top view. The two wheels *A* and *B* are moved by clockwork (not shown) and are constantly revolving in opposite directions, as indicated by the arrows. These wheels are not attached to the shaft upon which the wheel E is fixed, but are attached to sleeves which move without affecting that wheel except when they are joined to it by the clutches C or D. They are so geared that when the wheel E is joined to them its rim moves at the rate of half an inch per minute. Upon the shaft with the wheel E is also a loose sleeve F, which is free when the clutch C is not in action, but which moves with that wheel when that clutch is on.

The levers actuating the two clutches unite and move upon a common pivot, from which point they extend as an arm, which is capable of a lateral movement between two stops, bringing one or the other of the clutches into action.

Opposite to the wheel E the needle-bar passes through a guide which is furnished on the back with a small wheel taking the thrust of the gear and reducing friction. For a lower guide the needle-bar is furnished on each side with a rod parallel to the needle, and of nearly the same length. These rods are at such distance apart that they pass clear of the thermometer tube. They are not shown in the drawing, as they would lie directly in front of and behind the needle and tube.

The teeth of the clutches are partly V-shaped and partly square, or nearly so, as shown in Fig. 3; that is, they have slightly tapered sides but V-shaped points and bases, so that they enter freely, as entirely V-shaped teeth would do, and when in action they have no outward thrust. The V-shaped base strengthens the tooth and admits the point of the opposite tooth.

A very small spring on each side of the sleeve F holds it out of gear while the clutch C is off.

Beneath the clutch arm is a pressure spring, one end of which presses against the end of the arm and the other against a plate moving upon the same pivot with the arm, which plate also is capable of a lateral movement between its stops.

If this spring-plate is moved in either direction to its stop, carrying with it the base of the spring, the clutch-arm will be moved in the other direction and the clutch on that side will be brought into action; and if the position of the spring-plate with the base of the spring be reversed, the position of the clutch-arm will be reversed—that clutch will be disengaged and the other one will be engaged—the wheel E being moved and the needle-bar raised or lowered accordingly.

To the sleeve F is attached an arm which is connected by a draft rod to the spring-plate.

When the clutch C is in action—as shown in the drawing—connecting the wheel A with the wheel E and the sleeve F, raising the needle-bar, the arm of the sleeve F draws upon the spring-plate—moving to that side the base of the reversing-spring, which, when its base has passed the line between the pivot and the end of the clutch-arm, presses that arm to the other side, disengaging that clutch, loosing the sleeve F, engaging the other clutch, and reversing the motion of the needle-bar, which now descends.

The length of the arm on the sleeve F is such that when the needle-bar has risen half an inch the spring-plate is moved over, and the clutch-action is reversed.

When, by descending, the needle is brought in contact with the mercury and a circuit is made, the large electro-magnet, thus vitalized, attracts its armature, which is attached to a lever connected with and drawing upon the spring-plate, and moves the base of the reversing spring to that side, changing the position of the clutch-arm and reversing the action of the clutches and the movement of the needle-bar, while at the same time the recording point upon the needle-bar is, by its electro-magnet, driven into the paper and the temperature is recorded upon the scale.

The sleeve F, being loose, yields to the movement of the spring-plate, and is afterwards held by its clutch, and acts as before.

The action of the large electro-magnet is supplemented by that of a spring drawing upon the same side of the spring-plate, whose strength is such that it is not quite sufficient of itself to overcome the thrust of the reversing spring, but whose force is greatest when that of the electro-magnet, by reason of its distance from its armature, is least, the greatest possible portion of the work being thus put upon the clock-work and the least upon the battery.

This spring aids the electro-magnet, but does not in anywise reduce the effect of the reversing spring in holding the clutch to its work; so long as the base of that spring is unmoved its action is unimpaired. The resistance of these springs occurs only during the ascent of the needle-bar, which is, therefore, counterpoised to excess, and the resistance and the motion are thus rendered uniform. By reason of the form of the clutch-teeth before described there is no outward thrust upon the clutches while in action, and hence the reversing spring requires only to be strong enough to throw the arm over and to shift the clutches. The stop of the clutch-arm next the electro-magnet is an insulated plate to which the battery-wire leading from the magnet is connected, so that as soon as the arm has left the stop the circuit is again broken, although the needle may for a short time remain in contact with the mercury; the recording point is at once withdrawn, and thus makes upon the paper a single perforation which must be a true record of the position of the mercury in the tube, unaffected by friction or other disturbing cause, since this action must always take place at the moment of contact of the needle with the mercury, and these dots or perforations are repeated at the end of each interval of time required for the needle-bar to ascend and descend the required distance, which will be about two minutes with the wheel-motion designated.

The graduation of the scale upon the paper must correspond with the movement of the mercury in the tube of the thermometer as accurately as the graduation of the scale of an ordinary thermometer corresponds with the movement of the mercury in its tube.

If but one instrument of this sort is to be made this is very easy, the rate of motion is ascertained, a scale is made to fit it, and the paper is ruled to that scale.

In all thermometers heretofore made the scale has been made to fit the tube, but if more than one of these instruments is to be made it becomes necessary, or at least very convenient, to have one set of ruled papers that will fit all the instruments, and it then becomes necessary to reverse the practice and to make the tubes to fit the scale.

The rise and fall of mercury in a thermometer depends upon the proportion between the diameter of the tube and the volume of mercury in the tube and bulb, and while it is possible to construct these parts in such proportion as to obtain proximately a given motion, it is not possible thus to obtain it exactly.

The tube and bulb are made in separate parts, as shown in Fig. 1, of such size that when the tube is thrust half way into the bulb the volume of mercury filling the tube half way at 32° Fahrenheit is as nearly as may be properly proportioned to the diameter of the tube. If now there be found too much motion the capacity of the bulb is diminished by thrusting the tube further in, and *vice versa*, and the proper height of mercury at 32° for that purpose is marked upon the tube.

Mercury exposed to the air will slowly form a coating of oxide upon its surface. To prevent this a small quantity of glycerin or of oil free from oxygen is placed in the thermometer tube above the mercury. If, notwithstanding, the oxide shall accumulate to an inconvenient extent the observer in charge of the instrument will remove the thermometer from its place, and will put the bulb in warm water until the oxide is floated off. He will then supply the loss with pure mercury, determining the proper quantity by immersing the bulb in broken ice, when the mercury column should stand at the mark for 32°.

The whole apparatus, except the thermometer itself, can be enclosed and so protected from the weather and dust, while the thermometer is exposed to the air below.

The system is equally applicable to a barometric record, in which case, on account of the small range of motion, the needle-bar is connected to a lever, thus increasing the range of the record.

ELECTRICITY.

By A. E. OUTERBRIDGE, JR.

[Abstract of a Lecture delivered at the Franklin Institute, March 10, 1882.]

The subject of our lecture is one which offers unusual attractions at the present time, not only to the close student of science, but also to men of every profession or trade. The rapidity with which new discoveries in electrical science have followed each other of late years, together with the numerous practical and economical applications of the force to all sorts of industrial pursuits, and the prescience of still greater advances to come in the near future, has sufficed to render the subject an exceedingly popular one, and to lead many people to believe, whether truly or not, that electricity is the "coming force," which is to prove man's most useful servant, and is even destined, perhaps, to supplant steam power for many mechanical purposes, just as steam superseded human and brute force.

There is, I think, another explanation for the fascination attending, and the popular interest shown in, the study of electricity, which has little to do with its practical phase. I refer to the element of apparent mystery attaching to many of its phenomena.

There would seem to be a natural bias in many minds towards the mysterious, which not infrequently exhibits itself in an extraordinary